Geology of Sudbury Basin
Size

- Sudbury Basin is 62km long, 32 km wide and 15 km deep.
- Also located near the confluence of 3 major plates in the North American Craton, the Superior, the Grenville and the Southern.
Origins

• The Sudbury Basin or Structure was formed by the impact of a 10 km meteorite.
• This is the second largest impact crater in the world.
• The original crater is guessed to be about 250 km in diameter.
• Impact occurred about 1.85 billion years ago.
• Original crater altered by subsequent geologic processes
Sudbury Igneous Complex

- Localized around the rim of the basin.
- Formed by the recrystalization of the impact melt (i.e. magma)
- Made up of mafic norite, felsic norite, quartz gabbro, and granophyre
- Source of most of the ores being mined due to slow cooling of magma.
Sudbury Igneous Complex

- Two plutons, the Creighton and Murray, both of granite were brought to the surface after the impact.
- Both are along the south rim of the basin
The Whitewater Group

- Made up of breccia at the lowest layer.
- Also includes mudstone, siltstones.
- Very mineral rich and good for agriculture after weathering.
- This covers the floor of the basin
Mining and Rock Stability Issues in the Sudbury Mining District

Creighton Mine 1905
Why is Stability in Mining Important?

- Safety is #1 issue.

October 7th, 2007, Creighton Mine in Sudbury district experienced 3.7 magnitude quake.

- Result was rockbursts
- Rockbursts a main cause of accidents in mines and particularly in the Sudbury District
Seismic Events in Sudbury Mines

- Causes and Consequences
- How Problems are being addressed
Mining Induced Seismic Activity and Rockbursts

- Preexisting stress fields can release energy in the form of seismic events
- Can lead to rockbursts
  - Rockbursts reported in Sudbury as early as 1935
Result of a rockburst
Rockbursts

- **Two Categories**
  - Type I: Direct result of mining excavation
  - Type II: Occur at a distance away from mining, not in direct contact with applied stresses
Behavior of Microseismic Events

• Microseismic events align themselves with geologic structure; i.e. they follow the fault orientation.

• This was determined from study of the Strathcona Mine in the Sudbury district.
Stereonets showing seismic alignment with fault orientation

Fracture poles

Orientation of seismicity

Fault-plane solutions

Failure planes
Behavior of Microseismic Events

- Wave energy (P and S waves) gives insight to behavior
- From same study of Strathconia Mine, three energy regions were discovered:
  - (1) P-wave dominated
  - (2) S-wave dominated
  - (3) Combination
Energy Regions in Strathcona Mine
Implications of Energy Regions

- Events close to excavation dominated by non-shear failure.
- Events further away dominated by shear failure.
Solutions to Rock Stability Issues

• “Bulk” Method of mining has become popular
  – 95% of ore from Creighton Mine obtained by this method
  – Specific method: “Slot-Slash”
    • Used by Vale Inco
“Slot-Slash” Mining Method

- Minimizes number of needed blasts
- Increases number of available blasting faces
- Reduces seismicity
Vale Inco at the Creighton Mine in Sudbury
Safety Measures

• Procedure after excavation:
  – Vale Inco implemented following procedure for Creighton Mine:
    • Exit vicinity
    • Allow for seismic decay
      - Most mining induced seismicity from slipfaults right after blast
Telemining in Sudbury District

• Excavations are made remotely
  – Keeps miners out of potential hazardous situations like rockbursts

• Complications:
  – Difficult to implement due to current rock structure
    • Needs to be modified for accommodations.
Telemining Technology
Conclusion

• Rock stability and microseismic events not uncommon in Sudbury
• Research and emerging technology is increasing safety and efficiency
Environmental Affects

• Three main factors in environmental damage:
  – Roast Yards
  – Logging
  – Smelting
Roast Yard

• First step to processing nickel-copper ore
• Fumes are dispersed at ground level
• Ore heated in air
  – Sulfide oxidizes
• Ore burns for 2+ months
  – Sent to furnace for smelting
Logging

• Heavy logging to support burning
Smelting

• Stacks disperse fumes over a large area

• Smelter fumes contain:
  – Copper particles
  – Nickel particles
  – Sulfur dioxide

• Fumes affect the landscape long term
Vegetation damage

- First assessment, 1945: Murray and Haddow
  - Tree foliage severely burned
    - 35km NE
    - 20km N
    - 20 km S
  - Higher mortality/decreased growth
    - White pine: up to 40 km
    - Floor species: up to 20 km
Vegetation damage

• 1974: Whitby and Hutchinson
  – Proved that soil inhibits plant growth
    • Toxic components were water-soluble
      – Copper
      – Nickel
      – Aluminum
      – Cobalt (at lower levels)
Vegetation damage

• 1981: Amiro and Courtin (coinciding with Struik’s (1973))
  – Provide first detailed quantitative description of vegetation surrounding smelters
  • “Barren” area
    – Soil pH < 4.0
    – Land closest to smelters
  • “Semi-barren” area
    – Land more distant from smelters
Figure 2.7. The location of the Sudbury Basin and the major sites of roasting and smelting activity and Struik's (1973) "zones of site and vegetational stability" based on air photographs.
Impacts

• Logging
  – Erosion
  – Extreme frost action

• Metal Deposition
  – Toxicity
  – Soil pH interaction with nickel and copper

• Sulfur dioxide fumes
  – Sulfuric acid → acid rain
  – Soil pH relative to fume zone
Logging

• Soil erosion begins
  – Glacial till restrains/protects complete erosion of many areas
    • Coarse material (stones and boulders) still in place today
  – Frost action
    • Caused additional washing out of fines
Metal Deposition

• Metal contamination
  – Toxicity
    • Copper and nickel concentrations higher near smelters
    • Soil pH also higher near smelters
  – pH and nickel/copper interaction

<table>
<thead>
<tr>
<th>Fumigation zone</th>
<th>Mean pH ± SD</th>
<th>Mean total copper (mg/kg ± SD)</th>
<th>Mean total nickel (mg/kg ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy</td>
<td>3.8 ± 0.3</td>
<td>1250 ± 500</td>
<td>1930 ± 900</td>
</tr>
<tr>
<td>Moderate</td>
<td>4.3 ± 0.1</td>
<td>900 ± 300</td>
<td>750 ± 300</td>
</tr>
<tr>
<td>Light</td>
<td>4.7 ± 0.1</td>
<td>320 ± 80</td>
<td>400 ± 120</td>
</tr>
<tr>
<td>Perceptible</td>
<td>5.0 ± 0.2</td>
<td>200 ± 30</td>
<td>420 ± 120</td>
</tr>
<tr>
<td>None</td>
<td>5.0 ± 0.2</td>
<td>100 ± 20</td>
<td>200 ± 30</td>
</tr>
</tbody>
</table>
Sulfur Dioxide Fumes

• Largest affect on environment
  – Impacts largest area of land
  – Long term impacts

• Damages land and water environments
  – Land damage: peaked in 1960s
  – Water damage: peaked in 1970s
Sulfur Dioxide Fumes

• Contributes to erosion issues
  – Destroys both tree and floor plant life

• Some plant life thrives in high pH soil
  – White birch
  – Wild blueberry
Today

• New technology has greatly improved the area
  – Improved desulphurization
  – Furnace developments in smelters

• In 1993 SO2 emissions were less than one fifth (55 kt) of the 1970 output (320 kt) (Falconbridge)

• SO2 reduction by 87% from 1972 to 1994 (INCO)
Questions???